RESEARCHPROPOSAL

A STUDY OF SOME HEAT AND MASS TRANSFER PROBLEMS IN FLUID DYNAMICS

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1. Topic

A STUDY OF SOME HEAT AND MASS TRANSFER PROBLEMS IN FLUID DYNAMICS

1.1 Introduction

1.1.1 Fluids

Fluid can be defined as “A substance which deform continuously without limit due to the application of shearing stress, no matters how small it is.”

Fluids are usually classified as liquids and gases.

Liquid :A liquid have fixed volume but takes the shape of its container. Examples - juice, milk or water etc.

Gas:A gasdoes not have fixed volume and attains the shape of its container, no matter the size and shape of the container is, such as helium in a balloon, oxygen in the air, or air in a jar etc.

1.1.2Fluid Dynamics

A fluid is a substance which can flow from higher level to lower level andDynamics is the branch of mechanics which deals with the study of motion taking the cause into consideration, hence “Fluid Dynamics is the science treating the study of fluids in motion.”

1.1.3 Heat and Mass Transfer

Heat transfer

Heat transfer is the transit of thermal energy from one point to anotherpoint due to the temperature differences between two points.

Mass Transfer

The transport of one constituent from a region of higher concentration to that of lower concentration is called mass transfer. Refrigeration and air conditioning deal with processes that involve mass transfer.

1.1.4 Modes of Heat Transfer

Basically there are three modes of heat transfer namely Conduction, Convection and radiation.

Conduction

In conduction heat transfer takes place due to a temperature differences in a body or between bodies in thermal contact, without mixing of mass.The rate of heat transfer through conduction is governed by the Fourier's law of heat conduction.

$$Q = -\kappa A\left(\frac{dT}{dX}\right)$$

where'Q' is the heat flow rate by conductivity,'A' is cross-sectional area 'κ' is thermal conductivity., and'$\frac{dT}{dX}$' is the temperature gradient of the section.

Convection

In convection heat is transferred to a moving fluid at the surface over which it flows by combined molecular diffusion and bulk flow.The rate of convection heat transfer is governed by the Newton's law of cooling.

$$Q = hA(T_s - T_\infty)$$

where'T_s' is the surface temperature,'T_∞' is the outside temperature and'h'is the coefficient of the convection and A is cross-sectional area.

Radiation

In radiation heat is transferred in the form of radiant energy or wave motion from one body to another body.The rate of heat radiation that can be emitted by a surface at a thermodynamic temperature is based on Stefan –Boltzman law.

$$Q = \rho \cdot T^4$$

where,'T' is the absolute temperature of surface, ' ρ ' is the Stefan Boltzman constant.

1.2Fundamental Equations of the Flow of Viscous Fluids

1.2.1 Equation of State

Variables that depend only upon the state of system are called variables of state.The three thermodynamic variables exist and can be written as $F(p,\rho,T)=0$ where$p$ is pressure, ρ is density and T is temperature of the fluid.

1.2.2 Equation of Continuity

The equation of continuity expresses the law of conservation of mass.This equation expresses that the rate of generation of mass within a given volume is entirely due to the net inflow of mass through the surface enclosing the given volume; mathematically it can be expressed as

$$\frac{\partial \rho}{\partial t} + \frac{\partial}{\partial x_j}\left(\rho \upsilon_j\right) = 0$$

where, v_j is the j^{th} component of the velocity.

1.2.3 Equations of Motion

The equations of motion express the law of conservation of linear momentum. The equations of motion are derived from Newton's second law of motion which state that "Rate of

change of linear momentum =Total force."TheNavier-Stoke's equationsexplain the motion of fluids. For viscous compressible fluid, Navier-stokes equations written as

$$\rho\left[\frac{\partial v_i}{\partial t}+v_j\frac{\partial v_i}{\partial x_j}\right]=\rho f_i-\frac{\partial p}{\partial x_i}+\frac{\partial}{\partial x_j}\left[\mu\left(\frac{\partial v_i}{\partial x_j}+\frac{\partial v_j}{\partial x_i}-\frac{2}{3}\delta ij\frac{\partial v_\kappa}{\partial x_\kappa}\right)\right]$$

where, f_i is the external force, μ is the coefficient of viscosity.

1.2.4 Equation of Energy

The equationof energy express the law of conservation of energy.For viscous compressible fluids, the equation of energy is

$$\rho\frac{D}{Dt}\left(C_pT\right)=\frac{Dp}{Dt}+\frac{\partial Q}{\partial t}+\frac{\partial}{\partial x_i}\left(k\frac{\partial T}{\partial x_i}\right)+\phi$$

where, $\frac{D}{Dt}\equiv\frac{\partial}{\partial t}+v_j\frac{\partial}{\partial x_j}$, is 'material derivative'.

$$\text{and}\,\phi=\mu\left(\frac{\partial v_i}{\partial x_j}+\frac{\partial v_j}{\partial x_i}-\frac{2}{3}\delta_{ij}\frac{\partial v_k}{\partial x_k}\right)\frac{\partial v_i}{\partial x_j},$$

is heat transfer due to friction forces and is usually known as "dissipation function".

1.3 Boundary Layer Equations

In1904, Ludwig Prandtl suggested thatthe study of fluid motion around an object could be divided into two categories-

(1) A very thin layer in the neighborhood of the bodyknown as boundary layer in which the viscous effect may be considered to be confined, and

(2) The region outside this layer where the viscous effect may be considered as negligible and the fluid is regarded as inviscid.

With the aid of this hypothesis, he simplified the Navier-Stoke's equations to a mathematically tractable form, which are then called the boundary layer equations and thus succeeded in giving a physically penetrating explanation of the importance of viscosity in the assessment of frictional drag.

A solution of these limiting equations may thenreasonably be expected to describe approximately the flow in a laminar boundary layer for which Reynolds number (The ratio of inertial forces to the viscous forces)is large but not infinite. This is the basis of the classical theory of laminar boundary layers.

The equations of motion for a two dimensional unsteady incompressible flow are-

$$\frac{\partial u}{\partial t}+u\frac{\partial u}{\partial x}+v\frac{\partial u}{\partial y}=\frac{\partial U}{\partial t}+U\frac{\partial U}{\partial x}+v\frac{\partial^2 u}{\partial y^2}$$

$$\frac{\partial u}{\partial x}+\frac{\partial v}{\partial y}=0$$

where$x$ and y variables are respectively,the horizontal and vertical coordinates, u and v are respectively, the horizontal and vertical fluid velocities and U is the free stream velocity. The boundary conditions, under which theinse equations are usually integrated, are

y=0: u=v=0;

$y\to\infty$ u=$U(x, t)$,

1.4 Magneto Hydro Dynamics

The concept of MHD in fluid motion was initiated by Hannes Alfven in 1970.The fundamental idea behind MHD is that magnetic field can induce currents in a moving conductive fluid, which in turn polarizes the fluid and reciprocally changes the magnetic field itself.The equations governing the motion of a viscous incompressible electrically conducting fluid are

$$\nabla.\vec{v}=0$$

$$\rho\frac{D\vec{v}}{Dt}=-\nabla\left(p+\frac{\mu_e H^2}{2}\right)+\mu_e\left(\vec{H}.\nabla\right)\vec{H}+\mu\nabla^2\vec{v},$$

$$\nabla.\vec{H} = 0$$

$$\frac{\partial \vec{H}}{\partial t} + \left(\vec{v}.\nabla\right)\vec{H} - \left(\vec{H}.\nabla\right)\vec{v} = \upsilon_H \nabla^2 \vec{H}$$

$$\frac{\partial H_x}{\partial x} + \frac{\partial H_y}{\partial y} = 0,$$

$$\frac{\partial H_x}{\partial t} + u\frac{\partial H_x}{\partial x} + v\frac{\partial H_y}{\partial y} - H_x\frac{\partial u}{\partial x} - H_y\frac{\partial u}{\partial y} = \upsilon_H \frac{\partial^2 H_x}{\partial y^2}$$

$$-\frac{\partial}{\partial x}\left(\frac{p}{\rho} + \frac{\mu_e H_x^{\,2}}{2\rho}\right) = \frac{\partial U}{\partial t} + U\frac{\partial U}{\partial x} - \frac{\mu_e H_{x\infty}}{\rho}\frac{\partial H_{x\infty}}{\partial x}$$

The boundary conditions,

$y=0:$ $u=0,$ $v=0,$ $H_y = 0,$

$y \to \infty : u=U(x,t)$ $H_x = H_{x\infty}(x,t)$

1.6Review of Literature

Before submitting the research proposal I have gone through the following literature-

In 1972,Kalb et al.[5] studied the heat transfer to steady viscous flow in curved tubes of circular cross section theoretically for fully developed velocity and temperature fields under the thermal boundary condition of axially uniform wall heat flux with peripherally uniform wall temperature. The thermal-energy equation was solved numerically by use of a point successive-over-relaxation method.

In 1976, Thomas et al.[20] discussed thecorrelating equations for heat transfer by natural convection from horizontal cylinders to a cylindrical enclosure using conduction boundary layer model.They verified correlation is valid for heat transfer by conduction, laminar flow and turbulent flow.

In 1983,Kandilkar et al.[6] found the saturated flow boiling heat transfer coefficients the inside horizontal and vertical tubes. It was based on a model utilizing thecontribution due to nucleate boiling and convective mechanism.The proposed correlation extended to other fluids by evaluating the fluid-dependent parameter for that fluids.

In 1985,Osvair et al.[19] studied the natural convection phenomenon occurring inside a porous layer with both heat and mass transfer. According to them the natural circulation was driven by combination of buoyancy due to both temperature and concentration variations.

In 1990,Merkin et al. [12] analyzed the similarity solution for free convection boundary layer flow on a vertical plate with a prescribed surface heat flux. The solution was obtained from an integral condition for the whole boundary layer flow.

In 2000, N.P. singh etal.[17]discussed the flow of an incompressible electrically conducting viscous fluid past a steady moving semi-infinite vertical porous plate under the action of uniform transverse magnetic and constant heat flux. The analytical solutions for velocity field, temperature distribution, induced magnetic field,current density concentration field and the expressions for shear stress and rate of heat transfer were obtained and discussed in detail.

In 2001, Zhen et al.[9] discussed the theoretical and experimental investigation on film boiling heat transfer of water jet impinging on high temperature flat plat for the jet stagnation zone. A semi-empirical correlation was proposed for predicting heat transfer coefficient of film boiling.

In 2003,Merkin[11]studied the natural-convection boundary-layer flow on a vertical surface generated by Newtonian heating in which the heat transfer from the surface is proportional to the local surface temperature is discussed. The solution for downstream gives rise to a novel similarity system that was analyzed in detail, with solutions obtained for large and small values of the prandtl number.

In 2003,Atul et al.[18]analyzed the hydromagnetic heat and mass transfer in MHD flow of an incompressible, electrically conducting, viscous fluid, past an infinite vertical porous plate embedded with porous medium of time depended permeability under oscillatory suctionvelocity normal to the plate .The flow was affected by the difference in concentrations on material constitution.

In 2009,Makinde et al. [10] found the hydromagnetic mixed convection flow of an incompressible viscous electrically conducting fluid and mass transfer over a vertical porous plate with constant heat flux embedded in a porous medium.It was found that for positive values ofthe buoyancy parameters, the skin friction increasedwith increasing values of both the Eckert number (Ec) and the magnetic field intensity parameter (M) anddecreased with increasing values ofboththe Schmidt number (Sc) and the permeability parameter (K).

In 2009,Sibanda et al. [16] investigate the hydro magnetic steady flow and heat transfer characteristics of an incompressible viscous electrically conducting fluid past a rotating disk in a porous medium. It was found that magnetic field retards the fluid motion due to the opposing Lorentzforce generated by the magnetic field.

In 2012,Ravikumar[14]investigated the heat and mass transfer effects on MHD flow of viscous incompressible and electrically conducting fluid through a non-homogeneous porous medium in the presence of heat source, oscillatory suction velocity.From the point of applications model studied on the effect of magnetic field on the convection flow have been madeby several investigators.The flow wasaffected by the difference in concentrations on material constitution.

In 2012,LingaRaju et al.[8] discussed the effect of chemical reaction on unsteady convective heat and mass transfer flow of viscous fluid in a vertical channel bounded by wavy walls. The walls were maintained at oscillatory temperature and concentration.The non-linear equations governing the flow, heat and mass transfer were solved by employing a regular perturbation technique.The rate of heat and mass transfer on

the boundary walls were evaluated numerically for different variations of the governing parameters.

In 2014, Ahmad et al. [1] analyzed the effects of viscous dissipation and internal heat generation on combined heat and mass transfer . The MHD viscous fluid flow over a moving wedge in the presence of mass suction with the convective boundary condition were carried out for the various values of dimensionless parameter. They also studied the effect of heat and mass transfer and shear stresses over a moving wedge on a nonlinear MHD boundary layer viscous flow with a convective boundary layer in the presence of heat generation, viscous dissipation and mass suction using Ruge-Kutta fourth order method with shooting technique.

In 2015, Arifuzzaman et al.[2]studied analytically the combined heat and mass transfer of a viscous fluid along a semi-infinite vertical plate with large suction also the viscous fluid behaviors of heat and mass transfer over a vertical plate with large suction had been observed.

In 2015,Kishan etal.[7] found the viscous dissipation and variable viscosity effects on the flow, heat and mass transfer characteristics in a viscous fluid over a semi-infinite vertical porous plate in the presence of chemical reaction. The governing boundary layer equations are written into a dimensionless form by similarity transformations.The effects of viscous dissipation, variable viscosity, suction, and chemical reaction on flow, heat and mass transfer of a steadyincompressible Newtonian fluid past a vertical plate had been studied numerically using the implicit finite difference method.

In 2016, Coppola et al.[4] noticed the importance of definition of dimensionless parameter in defining a local correlation for convective heat transfer compressible micro scale flows. The correlation was validated through a series of numerical computation in both counter-current and co-current micro heat exchanger configurations. The main aim of the work was to look for a proper choice dimensionless parameters that allowed for a better understanding of the physics and

the definition of a strictly local correlation for convective heat transfer in compressible gaseous flow in micro-channels.

In 2018,Schaub et al. [15]discuss the influence of unsteady flow structures in natural convectional a heat transfer from a vertical flat plate to the air. Observation of the unsteady convection flow in the form of visualizations show a temporarily increased mixing of the boundary layer which also deviates distinctly from quasi-stationary development. In particular, a temporary occurrence of Kelvin-Helmholtz vortices can be observed.

In 2018,Babu et al.[3] deal with the effects of double diffusive, mixed convective flow of an incompressible viscous fluid through a vertical heated plate embedded in a non-Darcy porous medium under the influence of variable fluid properties numerically.

In 2018,Pandit et al.[13] found the boundary layer flow of an unsteady MHD free convection heat and mass transfer flow of a viscous, incompressible and electrically conducting fluid over an impulsively started infinite vertical plate in presence of thermal radiation.The unsteady MHD natural convection flow with heat and mass transfer of a viscous, incompressible, electrically conducting and thermal radiating fluid over an impulsively started vertical plate.Exact solutions of the governing equations were obtained using Laplace transform technique.

1.7 Objectives of the Present Study

The overall aim of our research work is :-

- To analyze the results already available on heat and mass transfer in fluid dynamics.
- To analyze the heat transfer in fluid by conduction and convection.
- The above researches and application provide a base for the motivation of the present investigation.

1.8 Plan of Work and Methodology

The present result will be carried out in three phases :-

- I will study the literature on the heat and mass transfer in fluid dynamics in detail.
- After that I will try to analyze and establishthe flows of fluids in channels, sheets or any porous/solid surface.
- In third phase I will verify my results with the special cases already exist and then try to generalize the results.

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